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ON THE EFFECT OF RELIABILITY OF SIMULATION RESULTS ON THE METHODOLOGY OF FLIGHT TESTING AND SIMULATION

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16. Abstract

Various methods of flight simulation are described and a comparison of the results obtained by flight simulators with flight tests are discussed. The VAK 191 B aircraft is used as an example of typical takeoff and landing performance for STOL aircraft. Diagrams of the aircraft attitude control during transition phases following takeoff and during landing approach are provided. Techniques used by the test pilot in conducting the flight tests are described.

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ON THE EFFECT OF RELIABILITY OF SIMULATION RESULTS ON THE METHODOLOGY OF FLIGHT TESTING AND SIMULATION

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You were able to realize from the preceding contribution that /93*
the reliability of the initial data used in simulation is of varying quality. However, by means of actual-part simulation, ground tests, mooring tower tests, aerodynamic calculations and simulations in the close-fit simulator, the behavior of the aircraft was to be predicted at least to the extent that a safe flight performance was possible to begin with. Subsequently, the first flights must be evaluated and the results can be compared with the results from simulation and, if necessary, simulation can be corrected. This method of proceeding in small steps leads to a greater reliability of the results from simulation, i.e., the predictability of new flight ranges becomes more reliable. I would like to explain this in more detail by the example of the takoeff and landing procedure for the first flights of the VAK 191 B (Figs. 1 and 2). In order to avoid hot-gas recirculation, a takeoff and landing procedure was selected and tried out in simulations which was not an exact vertical takeoff or landing. After short taxiing, the aircraft came to a standstill at an elevation of about 30 to 50 ft, so that recirculation was impossible. However, an evaluation of these flights showed that recirculation did not occur as much as expected, so that even during the first flights, step by step, the liftoff took place with constantly decreasing forward velocity until, finally, exactly vertical takeoffs and landings could be performed. The example is meant to show that with a low reliability of initial data the aspired flight condition is at first worked towards from the

* Numbers in the margin indicate pagination in the foreign text.

safe side until the desired result has been achieved. I would like to call this attitude a step-by-step procedure.

This manner of proceeding is not always applicable. It will /94
frequently be necessary to tolerate a sufficiently wide spread of initial data. This implies staying within the guaranteed safe, but perhaps not optimal, range. You might say that this way reserves are "put into your pocket." For this, again, a diagram.

In Fig. 3 limiting curves α over β at 47 and 88% of roll servo output have been plotted for one wind-blowing velocity each. That corresponds to approximately 40 and 90% of roll control moment consumption for the kind of nozzle characteristics. Accordingly, the range is certainly outside of the closed curve path, or to the left of the curve for $\beta < 90°$ and to the right of the curve for $\beta > 90°$. The crosshatching indicates the tolerance spread to be expected in accordance with the calculated data. At the start of the flight test, the permissible angle of sideslip will in each case lie outside of the tolerance spread, despite the fact that, among other things, the flight range will be very greatly limited. In the course of testing, a more exact position of limiting values can first be determined point by point and, if need be, the permitted range can be extended.

In many cases it will also be possible to perform a certain parameter variation, i.e., it is necessary to determine the critical influential parameters for certain flight conditions. These parameters must above all be varied towards the bad, i.e., the unsafe side, in order to recognize the range limits and to determine when a flight can become critical. This is also made clear in Fig. 3.

Until now, I have frequently spoken of a safe and unsafe flight range and its prediction. In this, I see at the start of a flight test an essential task of simulation, namely, to vouchsafe the safety of pilot and aircraft by means of sufficiently exact predictions of critical flight conditions. However, further along in the flight test it becomes necessary to render the simulation more reliable by means of current comparisons with flight test results. This can be accomplished by entering flight results in /95 diagrams obtained from simulations. In many cases it is possible to plot complete diagrams from not a few of the flights already at the beginning, as for instance, the critical ranges of the angle of sideslip, that can, for instance, be identified in Fig. 3 or that can be entered there. Similarly, frequency and attenuation of aircraft oscillations, functions of time, amplitude increases or similar items of the flight test can be determined. They must then be compared with the simulation, so that the simulation in turn becomes more trustworthy for an expansion of the flight range.

The necessity to compare flight results and simulation results leads to an approximation of flights in simulation and in reality. I would like to quote the following as an example: already during one of the first flights with forward acceleration, the aircraft was trimmed "hands off" and accelerated forward only by means of swivelling the thrust nozzles. The same flight was carried out in simulation, and that way it was possible to determine the trim of the aircraft by means of a comparison of the two "flights." This permitted a check to determine whether the moments assumed theoretically agreed with those in reality. The reasons for such an assimilation of simulation and reality are not only the same input but, above all, the exclusion of the effect of missing motion excitation. The simulator can reflect flight behavior only incompletely and the pilot must perform a certain "interpreter activity." Therefore, if an attempt is made to compare simulation and flight, this activity must also be made as easy as possible in order to obtain trustworthy results.

This leads me to another point of methodology of flight test and simulation: simulation must be constantly evaluated and compared by the pilot, i.e., the pilot must always be asked the question, whether he -- the pilot -- finds the aircraft again in the simulator. As mentioned above, the pilot has a certain "interpreter task," i.e., he must translate into actual flight behavior what he sees in the relatively imitative simulator, i.e., without motion excitations with a somewhat different instrumentation. Thus, the task results for the pilot whereby, in special problems, he limits himself, as far as possible, also in the /96 aircraft to what he sees in the simulator, so that later on, when repeating this condition in the simulator, he is able to make a better statement with respect to a comparison between flight test and simulation.

In addition, a careful and constant updating of the simulation program is essential for the reliability of results from simulation, i.e., changes or improvement of initial data derived from flight tests must be incorporated continuously and immediately in the simulation, so that with a step-by-step expansion of the flight range, the simulation program within the already-known flight ranges will actually correspond as well as humanly possible to the actual aircraft.

This brief contribution in the form of a discussion is meant to show how the desire for good reliability of the results from simulation for a new flight range will influence the methodology of simulation and flight testing. I spoke first of a step-by-step procedure; I then mentioned taking into account a sufficiently wide spread of initial data and went into detail regarding some points of pilot activity in connection with flight testing and simulation.

Summary

The effect of reliability of results from simulations accompanying flight tests on the methodology of flight testing and simulation is shown by way of several examples. Mentioned are iterative procedure, consideration of spread of initial data as well as a special adaptation of pilot activity.

After takeoff the pilot does not brake the forward speed until he attains an altitude of 30 to 50 ft by means of starting the aircraft in order to be certain to exclude any ground effect.

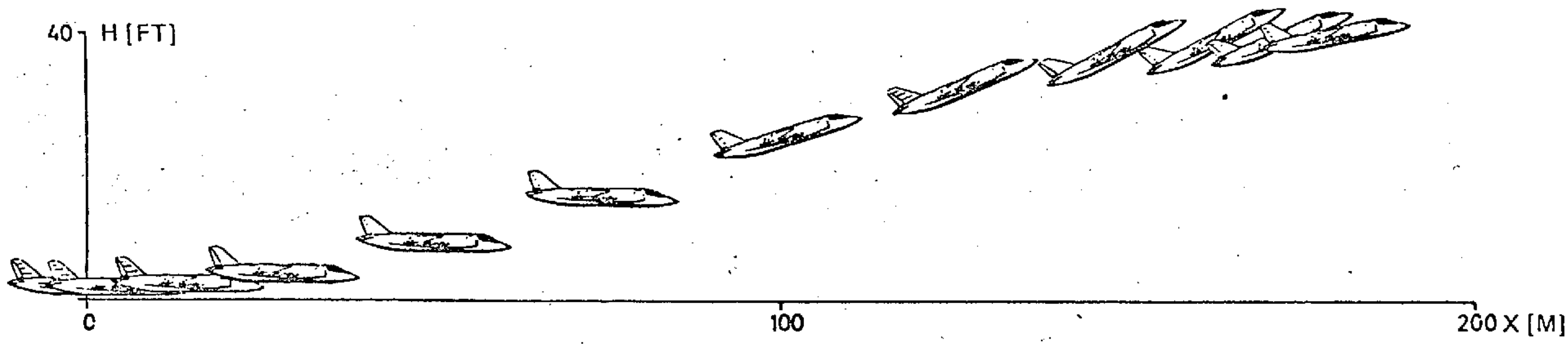
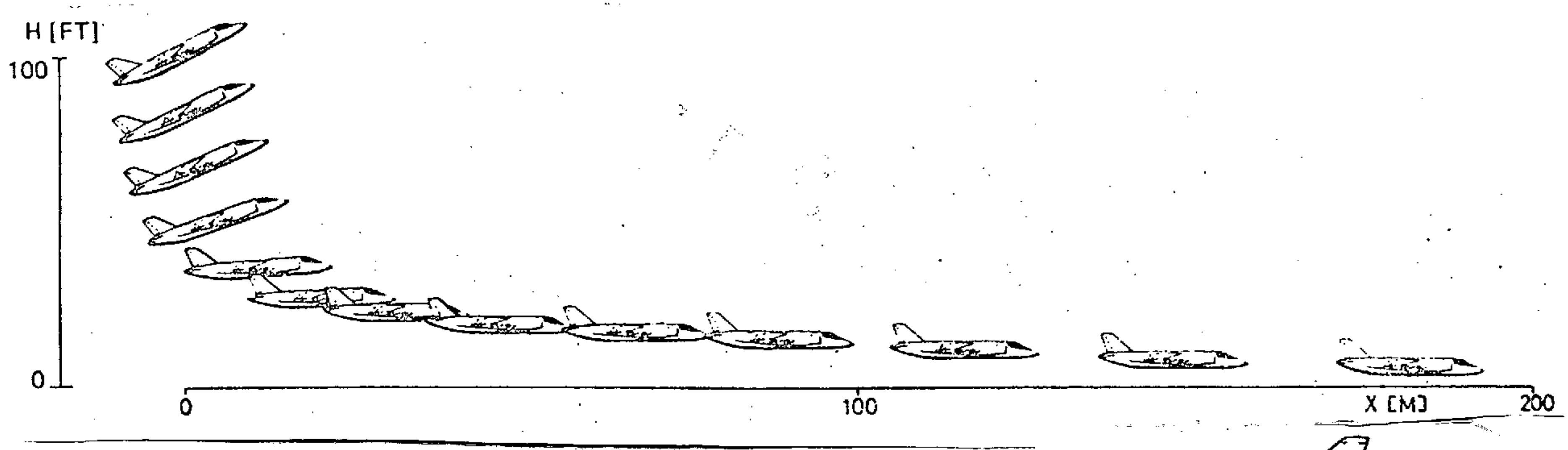


Fig. 1. Procedure for taxiing takeoff for a hovering flight.

The pilot

- o trims the horizontal position of the aircraft with respect to the upcoming touchdown (according to trim indicator)
- o swings the MTW beams to S $\leq$ 90°
- o without changing trim position, he pulls up so that the aircraft hovers
- o sets up a constant descent velocity
- o releases the stick at an altitude of 10 to 20 m.

Now the aircraft accelerates and touches down with a forward velocity.



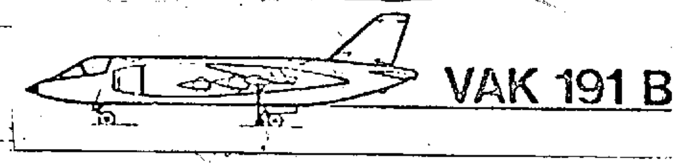
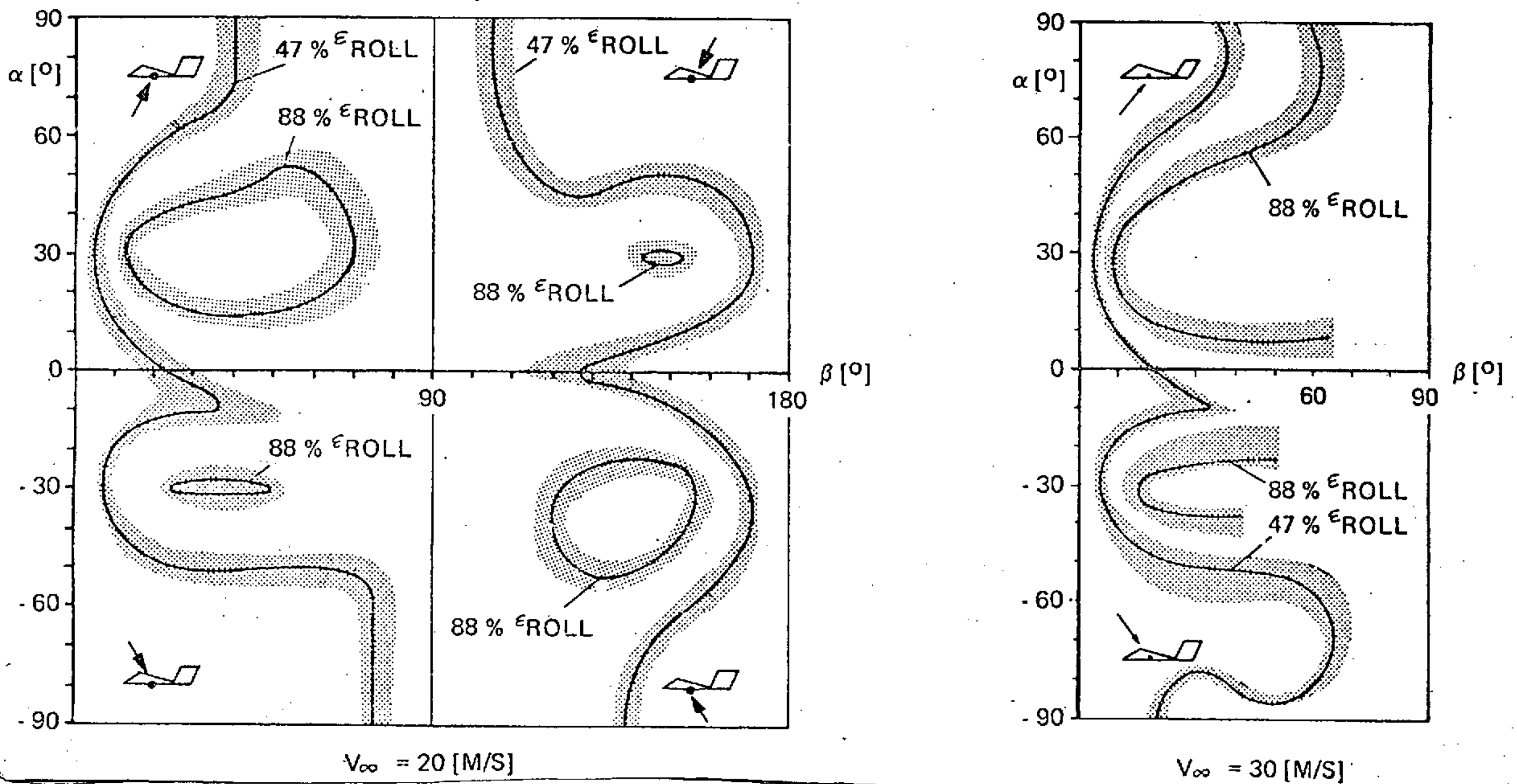


Fig. 2. Method for roll landing after hovering flight.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α [°]
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V∞ = 20 [M/S]
V∞ = 30 [M/S]

Fig. 3.